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NEW MOBILE FIRE FIGHTING EQUIPMENT FOR SHIPBOARD AIRCRAFT CARRIERS

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This report contains a survey of fire fighting problems associated with shipboard military aviation, identifies technological developments that affect these problems, and based upon an analysis of identified fire fighting needs, lists the functional requirements for a new fire fighting vehicle for shipboard use.

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SECTION I

INTRODUCTION

AMETEK/Offshore Research & Engineering Division (ORED) was contracted by the U.S. Navy to review the aircraft carrier firefighting requirements and capabilities and to prepare a statement of functional specifications for a new mobile firefighting vehicle for shipboard use.

~~AMETEK reviewed~~ Available literature and case histories, interviewed dozens of Navy and civilian personnel, and witnessed flight operations and aircraft carrier firefighting equipment demonstrations in an effort to place the shipboard fire hazard in an operational perspective.

This report contains a survey of firefighting problems associated with shipboard military aviation, identifies technological developments that affect these problems, and based upon an analysis of identified firefighting needs, lists the functional requirements for a new firefighting vehicle for shipboard use.

SECTION II

BACKGROUND

The U.S. Navy began putting mobile firefighting equipment on its aircraft carriers after the Forrestal incident in 1967, in which 134 people died and 21 aircraft were destroyed. An additional 161 people were injured and 43 aircraft damaged. Quick response to aircraft fires is vital if a catastrophe is to be avoided and the size and shape of the flightdecks make mobile equipment a suitable means of providing this response.

The first vehicles used were conventional crash trucks designed for use on land-based airports. In 1969 the Navy began developing a fire truck specifically for use on carriers where congested flightdecks make conventional crash trucks ineffective. This program resulted in the introduction of the A/S 32P-16 in 1979.

To achieve greater performance and reliability in its carrier-based, mobile, firefighting equipment, the Navy is now considering the development of an improved vehicle. This study recommends functional requirements for this vehicle in the light of recent experience and assesses the impact of these requirements on the P-16 design.

SECTION III

SURVEY OF FIREFIGHTING PROBLEMS

This chapter summarizes firefighting problems associated with shipboard military aviation. Technical information is discussed to put each problem in an operational perspective and to assess its potential impact on the fire scene. Technological developments are identified which will affect firefighting problems in future years.

A. AIRCRAFT MATERIALS AND HAZARDS

The aircraft materials and equipment described in this section present a recognized fire hazard by either contributing to the fire or otherwise endangering personnel at the fire scene. Trends in the utilization of the materials and in aircraft design are described as they will affect future firefighting operations.

1. Fuel

Aviation fuel is recognized as the principal problem in aircraft firefighting. Kerosene grades of fuel (JP-5 and JP-8) are standard for shipboard aircraft although aircraft arriving from an airfield may occasionally contain residual JP-4 fuel. Several dilutions are then required to bring the stored fuel to good quality JP-5. The fuel capacities of the types of aircraft operated from ships range from 242 gallons (UH-1N) to 5,086 gallons (KA-3B).

The fire properties of these fuels are listed in the NATOPS Aircraft Firefighting Manual (NAVAIR 00-80R-14). The kerosene grade is generally regarded as the least hazardous because of its higher flash point and slower rate of flame spread. However, under some conditions flame spreads at the higher rate regardless of the grade involved. When the fuel temperature is above the flash point, it exists entirely as a vapor, and in this state, the rate at which flame spreads in JP-5 approaches that of JP-4. The same is true in a mist condition formed by fuel escaping under pressure through a small leak in a fuel line or tank.

Successful development of fuel additives to retard fuel leakage or to rapidly make the contents of a leaking fuel tank inert appears to be many years away. Fuel thickeners add bulk to the storage volume and clog fuel pumps and engines. The Air Force is experimenting with compounds to make fuel spill contaminants inert and some progress may be expected in this area; however, this problem will probably be around for the next 10 to 20 years.

Fire tests of fuel pools have been conducted over several years to evaluate the characteristics, effects on aircraft structures and suppression requirements. Published results are used to develop firefighting requirements on airports and improved aircraft design standards. The Naval Aircraft and Ordnance Safety Group at NWC, China Lake, has recently started a

testing program aimed at characterizing the fire environment associated with fuel fires on flightdecks. Preliminary reports show temperatures above 2000°F have been observed. One- and limited two-dimensional suppression agents for this kind of fire geometry have been developed over the years, the most effective being Aqueous Film-Forming Foam (AFFF).

Running fuel fires have also been investigated. General characterization of this kind of fire is more difficult because the particular geometry of the fire has a great effect on its intensity. Where the fuel stream is agitated, more of it vaporizes and suppression is more difficult. The same result applies where the stream makes contact with hot metal. Agents such as AFFF are not especially effective against this kind of fire, and three-dimensional agents such as the dry chemical powders and the Halons are preferred.

2. Other Flammable Liquids

Other flammable liquids associated with aircraft are hydraulic fluid and lube oil. Although present in smaller quantities, and less flammable than fuel, those liquids are a hazard when involved in a fire. They have flash points higher than JP-5, but the flammability of the vapor phase and of a mist is explosive, just as with fuel.

The Navy is switching its standard aviation hydraulic fluid to MIL-H-83282, with a flash point of 400°F. This is 180

degrees above the flash point of the former standard fluid. The standard aviation lube oil has been MIL-L-26999 (flash point: 475°F) for several years, and no change is currently planned. Less combustible hydraulic fluids have been developed; however, these fluids are also considerably heavier, and present problems with toxicity. These facts suggest that these materials will present fire hazards on aircraft for at least the next decade.

Freon and other refrigerant fluids are used in deicing systems on some aircraft. They are regarded as combustible, but their combustibility is low. They are present in very small amounts, and compared with other fluids, they do not present significant firefighting problems.

3. Ignition Sources

Common ignition sources for the above flammable liquids are contact with hot surfaces, hot metal slivers, and static electric discharge. Spontaneous combustion of these liquids will also result from contact with oxygen in compressed or liquid form, often with explosive violence. Care in aircraft design and shipboard operating procedures is invoked to reduce the fire potential. However, perfect care only reduces the frequency of major fires, and all control may be lost due to aircraft damage resulting from a crash or from the fire itself. Therefore, the design of the tanks and distribution systems for these materials is an important consideration.

4. Oxygen

Oxygen as a compressed gas or liquid is present in all the Navy's shipboard aircraft except the smaller helicopters. In strictly technical terms it is not a flammable fluid, however its involvement will rapidly intensify a fire, making it hotter and harder to put out until its supply is exhausted. It can also produce an explosion by simply coming into contact with a petroleum-based substance. Techniques for dealing with this problem are limited to trying to stem the flow of oxygen or removing its source. As with fuels, prevention is the best solution and depends on good installation design and safe handling practices.

The requirement for compressed and liquid oxygen is being eliminated by installing On-Board Oxygen Generating System (OBOGS) equipment, which produces an oxygen-rich gas mixture from air bled from the engine intake compressor, using a molecular sieve. In essence, oxygen for high-altitude life support is generated in flight and does not have to be stored in compressed form with the AV-8A/B, TAV-8B and the T-45A. OBOGS is also programmed for retrofit to the AV-8A/C. Proposals have been prepared for retrofit to all other fixed-wing aircraft normally found on carriers by FY92. If accepted, this will virtually eliminate this hazard from the Navy's flightdecks, but, for the intervening period, crash crews must be prepared to deal with it.

5. Tank Protection

The tanks which carry these materials in the aircraft are important factors in assessing the hazard presented by a crash. A variety of fuel tanks are used in naval aircraft to take maximum advantage of space and weight; there are internal tanks, integral tanks, and external tanks, depending on the need and the location within the plane. The principal problems are leaks, ruptures, and vapors in the tank ullage above the fuel.

Crashworthy fuel tanks are designed to withstand a 65-foot drop without rupture and to seal any broken fuel lines. This criteria and the technology have proven effective in reducing the hazard in postfire crashes. Most of the Navy's helicopters are now provided with such tanks, and the F/A-18 has small crashworthy tanks in the fuselage for a reserve fuel supply. The weight penalty for this protection will not allow general use of the technology on military aircraft.

Flash-suppressing foams are used in some of the fuel tanks of the F/A-18 and are being retrofitted to certain tanks in other fighter and attack aircraft. This step is being taken to reduce the potential for explosion of the vapors in tank ullage, and tests have demonstrated its effectiveness; however, the tank walls can melt or rupture and release the fuel and vapors which are subject to burning.

Inertion fuel tanks are in development to prevent the burning of these vapors. One approach uses nitrogen to fill the tank ullage as the fuel is depleted, the nitrogen being generated from air by a molecular sieve. Such systems are being developed for cargo planes, helicopters, and patrol aircraft. Another approach uses Halon in the tank ullage; these systems are being developed for fighter and attack aircraft.

Halon fire-extinguishing systems are already in service on some aircraft. Enlarged systems are in development which will include not only fuel tanks but also enclosed spaces surrounding the fuel tanks where applicable. This crash-sensitive triggering device will automatically release the Halon into these spaces. Such a device is presently in use on the H-53E helicopter.

This program for reducing the severity of postcrash fires includes retrofit of existing aircraft as well as new-production planes. Roughly 10 years will be required, with priority given to selected aircraft. Improvements have already been seen in the incidents involving helicopters and further improvement can be expected.

The LOX converters (tanks) used on naval aircraft are presently designed for crash worthiness, and experience has shown that the design standards are effective. The converters remain intact even when they have been torn loose from the aircraft due to the impact of the crash. Prompt removal from the fire area is

necessary to prevent the boil-off gas from becoming involved in a fire.

6. Combustible Materials (Class A and C)

Materials in this category are used in various places on the aircraft and consist chiefly of natural rubber or synthetic materials such as plastics and fabrics. The many types vary widely in their fire properties, but those selected for aircraft use are subjected to flammability tests with the standards set appropriate for their use. As a group, these materials burn easily when exposed to sufficient heat, but compared with the flammable materials, the fires are readily extinguished with the common firefighting agents.

Some composite materials, such as carbon or boron fibers in a resinous binder, are gaining wide use in aircraft structures in place of light metals. Burn-through times are short, but no major extinguishing problems are presented. The smoke from these fires has been found to contain fine particles which cause damage to exposed aircraft, principally engines and electronic gear. Possible health hazards are under investigation. Composites are presently used on the RF-8G, the F/A-18, the S-3A and on some F-4s and F-14s. It is expected that they will appear on future aircraft as well.

Natural rubber is the standard tire material for all naval aircraft. Rubber stores heat as it burns and requires

cooling to prevent reflash. No new material is being developed to take the place of rubber.

Electronic components contain many combustible Class A and C materials. New electronic systems are in development for the various aircraft, but no new materials are foreseen with different fire hazards.

As the science of flammability testing and standards develops, the fire and health hazards presented by these materials will be better known and cockpits can be made safer. However, no changes are foreseen in the firefighting equipment or techniques needed to combat these fires within the next 10 years.

7. Combustible Metals (Class D)

Magnesium is commonly used on aircraft structures, but, because it is corrosive in the marine environment, it is not in wide use in naval aircraft. Some castings in the S-3A and transmission housings on the Navy's helicopters are made of magnesium alloys. Because of its combustibility, magnesium is also used in warheads of some weapons and in pyrotechnic devices. As a structural material, however, the Navy will eventually phase out magnesium as the present generation of aircraft is retired from service in 20 years or more.

The ignition temperature of magnesium is close to the melting point and varies somewhat from alloy to alloy.

The range of temperatures is roughly 800-1200°F and well within the range of fuel-fire temperatures. Magnesium involvement in aircraft fires is well-documented, as are the practical problems in dealing with magnesium in the postcrash environment. The best approach is to prevent the magnesium from reaching its ignition temperature, and because of the time required with large pieces, this is often possible when prompt attention is given. Halon agents are not recommended for use against fires because of a possible violent reaction with the burning metal.

Titanium has been used in turbine blades of aircraft engines for a long time. It is also being used as a structural material on the F-14, the F/A-18 and the S-3A. Because of its high cost, titanium will not be used extensively in the future, but its use for particular parts is likely to continue for a long time.

The ignition temperature of solid titanium is 2,900°F. The high temperature makes the large pieces of titanium used on aircraft structures extremely difficult to ignite; the turbine blades, on the other hand, are smaller and more easily ignited, and their occasional involvement in engine fires is observed.

Titanium ignites spontaneously when exposed to liquid oxygen and/or compressed oxygen gas. If either of these fluids contacts titanium in a crashed aircraft, the resulting fire would be difficult to extinguish.

Lithium is being used in the batteries of certain sonobuoys. It is also planned for use in the motor sections of the advanced lightweight torpedo (ALWT) being developed by the Navy. It burns vigorously at temperatures above 356°F and reacts with water to form hydrogen which burns with explosive violence. These hazards are being addressed in the development programs involved, and suitable safety standards are receiving attention to prevent exposure of the lithium to water or heat. This problem is compounded by the fact that the items containing lithium are stored in the bomb bays of the S-3A where direct measures to protect the items cannot be applied immediately.

In solid form, aluminum is not regarded as a combustible metal; however, a burning reaction in aircraft fires has been observed. It has been the principal material of aircraft structures for a long time, and has only recently given way to composite materials for certain components. It is known to burn in oxygen at temperatures above 1800°F, but has never been scientifically burned in air. Fire problems associated with aluminum in aircraft fires are its loss of strength at elevated temperatures and its rapid melting at 900-1200°F. Aluminum sheets can melt rapidly during a fire and create the impression of burning.

8. Ejection Rockets and Release Cartridges

These items are parts of the various escape and releasing mechanisms of some aircraft. While not considered ordnance, they

share some important characteristics and are designed to strict standards for slow cook-off behavior. The rockets on the ejection seats are shielded inside the cockpit to delay reaction, and cook-off temperatures are above those which a pilot can survive. In the cook-off tests, burning reactions are observed. The release cartridges are too small to have an adverse impact on the crash scene.

No new technology in this equipment is planned for introduction in the next several years. Some aircraft may receive a retrofit of ejection rockets attached to the canopy release system to propel the canopy during high "g" maneuvers. This will affect the procedures for pilot rescue, but it will not introduce new concerns for firefighting techniques or equipment.

9. Materials Summary

Tables 1 and 2 summarize fire hazards on existing aircraft.

B. AIR-LAUNCHED ORDNANCE

The chief complication to fires in naval aircraft is the presence of ordnance. Exploding weapons can scatter the fire and hamper firefighting operations. The scattering fire may involve additional aircraft, involving still more weapons, and start a chain reaction across the flightdeck. Prevention is the only means of dealing with this problem.

TABLE 1. SUMMARY OF FLAMMABLE FLUIDS ON NAVAL AIRCRAFT

AIRCRAFT	FUEL (Gals) INT	FUEL (Gals) EXT	MISCELLANEOUS FLAMMABLES *	OXYGEN
A-6E	2344	1500	Deicing Fl.	LOX
A-7E	1496	1200	Deicing Fl.	LOX & OXY
AV-8B	1102	1187	-	LOX
F-4B	1903	1346	-	LOX
F-14A	2337	900	-	OXY
F/A-18	1544	900	-	LOX
KA-3B	5086	N/A	Deicing Fl.	LOX
KA-6D	2344	1800	Deicing Fl.	LOX
EA-6B	2268	1200	Deicing Fl.	LOX
E-2C	1800	N/A	Deicing Fl.	LOX
C-2A	1824	N/A	Deicing Fl.	OXY
S-3A	1933	600	Freon Gas	LOX
AH-IT	517	N/A	-	N/A
UH-IN	242	N/A	-	N/A
SH-3G/H	700	N/A	Deicing Fl.	N/A
CH-46D	760	N/A	Deicing Fl.	N/A
CH-53E	638	650	-	OXY
SH-60	592	N/A	-	N/A
OV-10A	258	230		OXY

* All aircraft have lube oil and hydraulic fluid.

TABLE 2. SUMMARY OF COMBUSTIBLE MATERIALS ON NAVAL AIRCRAFT

AIRCRAFT	COMPOSITES	METALS *	ORDNANCE
A-6E			Yes
A-7E			Yes
AV-8B	Carbon		Yes
F-4B	Carbon		Yes
F-14A	Carbon/Boron	Titanium	Yes
F/A-18 **	Carbon/Boron	Titanium	Yes
KA-3B **			
KA-6D **			
EA-6B **			
E-2C **			
C-2A **			
S-3A	Carbon	Titanium Magnesium	Internal
AH-IT **		Magnesium	Yes
UH-IN **		Magnesium	
SH-3G/H **		Magnesium	Yes
CH-46D **	Carbon	Magnesium	Cargo
CH-53E		Magnesium	Cargo
SH-60	?	?	Yes
OV-10A **			Yes

* Aircraft engines commonly contain titanium turbine blades

** Contain batteries

1. Ordnance Cook-off and Cooling

Ordnance cook-off happens when the materials used in the weapons react chemically at temperatures above 300°F to produce fires, deflagrations, and often more violent reactions. In some weapons the process occurs in stages with one component burning slowly and producing heat, which then sets off a secondary, high-order reaction. Missiles and similar weapons have motor sections as well as warheads which will have different cook-off characteristics. Sympathetic detonations occur in some weapons when a nearby weapon reacts to the heat. Furthermore, the reactions occur with little or no warning, often with devastating results.

Experiments have been conducted at the Naval Weapons Center, China Lake, on the rate of heating of weapons when exposed to fuel fires and on the rate of cooling when exposed to normal streams of water and AFFF. Normal cooling rates are two or three times faster than heating rates, proving that it is possible to prevent cook-off by spraying these agents on the weapon -- provided the action is taken in time. Simple cooling in air is too slow to be effective once a weapon has been exposed to flame. It cannot be assumed, however, that the weapon is safe when coolant is applied; the weapon must be cooled throughout, and the coolant must be applied for several minutes. This is especially true of those weapons which exhibit staged reactions that generate heat inside the case.

Experiments have also shown a significant temperature rise inside a weapon after cooling has been initiated outside. This delay gives rise to the concept of a point-of-no-return in ordnance cook-off. Attempts to measure this time period for some weapons have been made, but the results are uncertain. The predictability of the cook-off process itself is low, and, when coupled with the problems of predicting the cooling process, the results are difficult to interpret. It is important to keep in mind, however, some lead-time is involved and measured cook-off time for a weapon does not fully describe the problem in fire-fighting.

2. Weapons Safety Criteria

The safety standards for the Navy's air-launched weapons, as related to aircraft firefighting, involve shock resistance and cook-off characteristics. Before being approved, a new weapon must pass the 40-foot drop test and a bullet impact test. It must also pass a rapid cook-off test and any special tests appropriate to the nature of that specific weapon design. In the rapid cook-off test, the weapon is subjected to a 1650°F fire. Both cook-off time and the character of the reaction are measured. This test is repeated often enough to provide a statistical evaluation of the cook-off behavior of the weapon.

Acceptance of a weapon is based on overall rapid cook-off performance. A weapon may be approved if there is no reaction

greater than burning within 5 minutes or no reaction greater than deflagration after 5 minutes. Deflagration in this sense means that the reaction does not extend beyond 50 feet. Higher-order reactions will result in the weapon design being subjected to special review for its utility, for possible modifications, and for restrictions which can be placed on its use.

3. Weapons Safety Program

The above criteria for crash-fire safety have only recently been applied generally to air-launched ordnance and new technology is being developed to improve cook-off performance. Weapons are being developed with insensitive explosives, ejectable fuses, and venting features in the component housings to meet the safety criteria.

For the older weapons, the new standards have created more problems. In some cases the new technology affects the configuration of the weapon or its performance. Thermal coatings are being used on the Mk 80-series bombs and derivative weapons to prolong the cook-off time. The same approach has been applied to rocket launchers. Tests are being conducted to determine how these coatings affect the flight characteristics of the missiles. Further work is being conducted to reduce the intensity of the reactions.

Many of the weapons in the Navy's inventory fall short of the new standards, and no universal solution can be found to the

many design problems. A program has been initiated within the Navy to correct this situation on a case-by-case basis, including the development of the technology for retrofit of the existing inventory. A preliminary assessment shows that 10 years will be required to complete the retrofit with present production capabilities. Because of unanswered technological and funding questions, more time may be required to reach the final goal, and intermediate objectives have been set which will allow progress to be made within this time period.

To illustrate the cook-off characteristics of the present inventory of conventional air-launched weapons, Tables 3 and 4 are weapon-by-weapon lists showing current information and estimated completion dates or dates for initial operational capability (IOC) for weapons now in development. The information on cook-off characteristics for in-service weapons comes from tests at the Navy's test facility, but some of it is preliminary in nature or does not reflect current technological capabilities for weapons designs. It represents the best information available pending publication of the revised cook-off manual (TP-75-22). For data on weapons still in development the information is preliminary and is intended only to reflect the characteristics of the design in the latest form for which information is available.

TABLE 3. AIR-LAUNCHED ORDNANCE COOK-OFF SUMMARY

In-Service Weapons		Present Cook-Off Characteristics Time (Minutes) Motor	Warhead	Reaction **	****
Mk-80's	G.P. Bombs *		5 +	DET-DEFL	FY88
Mk-77	Fire Bomb		5 +	HAZARD-100'	93
Mk-20	Rockeye *		5 +	SYMP. DET.	94
CBU-59	APAM		2-3	DET-DEFL	?
CBU 55/72	FAE		**	**	--
5-inch	Zuni (TP)		5 +	SYMP. DET.	93
2.75-inch	Rocket (TP)		5 +	SYMP. DET.	93
AIM 7	Sparrow	1-2	2-3	EXPL-DEFL	87
AIM 9	Sidewinder	0-1	2-3	EXPL-DEFL	87
AIM 54	Phoenix	*	3-4	DET-DEFL	87
AGM 45	Strike	1-2	2-3	EXPL-DEFL	90
AGM 78	Standard Arm	1-2	4-5	DET-DEFL	89
AGM 88	Harm	0-1	**	EXPL	93
AGM 84	Harpoon		**	**	--
AGM 65	Maverick	3-4	**	EXPL	90
AGM 62	Walleye		2-3	DEFL	89
BGM 71	Tow	1-2	?	No Data	90
AGM 123	Skipper	1-2	5 +	DET-DEFL	90
MK-46	Torpedo *		2-3	DEFL	90
MK-52/55/56	Mines		1-2	PDET-EXPL	93
20 mm	M 61 gun		2-3	EXPL-DEFL	90
20 mm	MK 11 gun		?	No Data	Obs.
30 mm	ADEN gun		?	No Data	?
7.67 mm	M 60 gun		?	No Data	?

* Including derived weapons
** Meets MIL-STD-1648A(AS) for rapid cook-off
*** DET - Detonation EXPL - Explosion
PDET - Partial DET DEFL - Deflagration
**** Estimated Retrofit Complete

TABLE 4. AIR-LAUNCHED ORDNANCE COOK-OFF SUMMARY

Weapons In Development (Preliminary)		Present Cook-Off Characteristics Time (Minutes) Motor	Warhead	Reaction **	****
AIM 9-C	Sidearm	0-1	**	EXPL-DEFL	FY85
AGM 114	Hellfire	**	**	**	84
25 mm	GAU-12 gun	**	**	**	--
	AMRAAM			No Data	88
	ALWT			No Data	85

* Initial operational capability scheduled
** Meets MIL-STD-1648A(AS) for rapid cook-off
*** DET - Detonation EXPL - Explosion
PDET - Partial DET DEFL - Deflagration

The cluster bomb, CBU-59/B (APAM), is a special case. This weapon has a minimum cook-off time of 2-1/2 minutes. Individual bomblets react violently, and sympathetic detonations of several bomblets can occur. Bomblet reactions are known to continue for 20 minutes. Found on some aircraft carriers, the weapon presents a major hazard to firefighters. The Naval Aviation Plan shows that no new weapon is being developed to replace the cluster bomb, nor is there any plan to retire it from active service. However, the cluster bomb is not being included in the weapons safety program and no plans have been made to improve its cook-off characteristics. This is the only such exception found during this investigation.

Special weapons are not included in these tables. As a group they present better cook-off characteristics than conventional weapons, but improvements for them are also being

developed. Their cook-off reactions do not result in explosion problems greater than conventional weapons, but they introduce contamination problems for which special equipment and expertise are needed. When special weapons are involved, crash crews can expect assistance from the special ordnance personnel appropriate for the type of weapons deployed.

4. Assessment of Cook-Off Test Data

The standard cook-off test is a systematic approach to evaluating the rapid cook-off characteristics of a weapon and is being used to improve weapon behavior in a crash fire or similar situation. It also allows some judgments to be made relating cook-off reactions to required crash response. Relating the measured cook-off times to actual crash situations cannot be done with a high order of precision because the rates at which real fires intensify and the degree of exposure are too variable.

During the standard cook-off test, each weapon is exposed to a heat flux of 10-15 BTU/Ft^2/Sec at an average temperature of 1650°F. The temperature rise in the first 30 seconds after ignition is typically 1000°F, but, instrumented tests of large pool fires show heat flux values twice this high inside the flame region and half this high outside it. The time to reach maximum intensity is approximately the same for pool-fire tests as for cook-off tests.

Consequently, the standard cook-off tests can be used for reasonable prediction of a worst-case result for the weapons with short cook-off times. For weapons showing larger cook-off times, the cook-off test may overstate the amount of time before a reaction can be expected in a worst-case event without preventive measures being taken. The test results are suitable for a guide in weapons design, but ordnance-cooling measures should be started much sooner in these cases.

5. Significance of Test Data to Crash Response

The firefighting concept of rapid intervention arises from the observation that most large fires start small, then expand and intensify. In aircraft firefighting, this process can occur within 1 minute and only a quick response can avoid a major conflagration. The concept recognizes that, in this initial period, firefighting resources are limited and may not be well-coordinated. It is important to direct the initial response of fire suppression, but the cook-off times for the missiles cannot be disregarded.

As long as measured cook-off reactions are intense and occur in less than 2 minutes, initial firefighting response must be directed at fire suppression and cooling within the immediate vicinity of the ordnance. Furthermore, for weapons with cook-off times under 1 minute, initial response must be made in less than 30 seconds and concentrated in the immediate vicinity of those weapons.

As shown in Table 3, the early cook-off reactions are of such magnitude that no reason is seen to adhere strictly to a 50-foot standoff distance during initial response. Every advantage should be gained by approaching as close as the heat will allow, or as required to effectively suppress the fire and to cool the ordnance. As the objectives of the ordnance safety program are achieved (roughly 10 years), the initial response can still be made from close-in. The sustained response, however, will need to maintain the standoff distance while dealing with fires which extend beyond a 5-minute safe period.

Even when the only reactions expected during the first 2 minutes are burning reactions, the initial response should follow the above concept. The materials used for rocket propellants make fires which are difficult to put out, and expose adjacent weapons to a source of heat not accounted for during the standard ordnance tests. Such fires will also enhance the possibility of reflash in the area involved and may otherwise hamper fire-fighting activity. A few weapons already fall in this category, but it will be several years before possible effects of burning ordnance materials will determine the appropriate form of initial response to crash fires.

C. SHIPBOARD FIRE-SUPPRESSION EQUIPMENT

Firefighting systems on Navy flight and hangardecks have evolved to keep up with the requirements of modern naval aviation

and the developments in fire-suppression agents. The main system is an AFFF/seawater system, backed up with auxiliary agents in hand-portable or truck-mounted extinguishers. The overall plan includes ship maneuvers, rescue, and salvage/disposal operations. The following describes these systems, their capabilities, and their roles in firefighting.

1. Aircraft Carrier AFFF/Seawater System

The main-line, fire protection role for the flight and hangardecks rests with this system, actually a series of semi-independent systems, each of which serves a separate zone. Seawater from the ship's firemain passes through one of the several HI-CAP stations where AFFF is injected into the water. The mixture then passes through its distribution lines to hose stations and sprinkler outlets in a certain part of the ship. Remote control panels are provided at various locations.

Each HI-CAP station has a 600-gallon tank for storage of AFFF concentrate and two pumps with proportioning equipment to deliver a 6 percent mixture. One pump serves the flightdeck sprinkler system and the other is a two-speed pump which serves both hangardeck and flightdeck hose-stations. The station is manned continuously during Flight Quarters and is provided with communications and a local control switch.

The flushdeck nozzles on the flightdeck are of two types. The landing area is served by jet-type nozzles which throw a

stream from the edge into the center of the area. The rest of the flightdeck is served by sprinkler nozzles which cover a circular pattern. The nozzles are designed for 30 gpm at 30 psig and normal service pressures are much higher. The nozzles are arranged to provide an application density of 0.06 gpm/ft^2 at design conditions. The streams reach a height of 3 to 4 feet above the deck. No protection is provided to the catwalk around the flightdeck, and only limited protection is provided to the elevators.

Control switches for the flushdeck sprinkler system are provided to Primary Flight Control, the Bridge and the Flag Bridge. Each switch is numbered to correspond with the flight-deck zone it serves, and charts are provided to aid in zone identification. Switches are also provided which allow the application of plain seawater. System response times during tests show that in 10 to 15 seconds from switch actuation the system is in its design operating mode.

Certain problems with the flushdeck system have been revealed by past experience. Individual nozzles becoming plugged by dirt is a chronic problem. The control valves in the seawater or the AFFF concentrate circuit may stick in the open or closed position, affecting the performance of an entire zone. Exercise of the system is restricted while the ship is in port, or when aircraft are on the flightdeck, making control more difficult.

Problems with this system at a crash scene have also been observed. The nozzle streams can be blocked by crash debris or by adjacent aircraft and thus fail to provide the needed coverage. The streams are not effective against any fire more than 3 feet above the deck. Streams also reduce the visibility of the crash crew, hampering the firefighting effort. These problems aside, when the system is well maintained it has proven very effective against pool fires and for containing running fuel fires. It is also effective for ordnance cooling when the weapons are close to the deck surface.

AFFF hose stations are located at intervals in the catwalk around the flightdeck and on the island bulkheads. Each station has two hoses and a control switch. The hoses must be long enough so that any point on the deck can be served by at least two hoses from different stations; in fact, most places can be reached by four. If fire occurs, nearby hose teams can respond in 30 to 45 seconds; usually, four hose teams can be on the scene in less than 1 minute.

The AFFF system on the hangardeck involves an overhead sprinkler system and hose stations. The overhead system is designed for an application density of 0.05 gpm/ft^2 using conventional ceiling nozzles to provide a circular and outward pattern to the stream. The sprinkler system is controlled by switches in the CONFLAG stations, two of which are located in each bay.

These stations are manned continuously whenever aircraft are aboard. The fire doors between bays and at the elevator hatches are also controlled at these stations. Additional protection is provided by the several hose stations along the bulkhead in each bay.

The AFFF capability of the aircraft carriers is being enhanced by the provision of a central storage tank for 6,000 gallons of concentrate. When completed, this installation will have a transfer system leading to each HI-CAP station. Another increase in the capability under consideration is converting the proportioners to make a 3 percent AFFF mixture, thereby doubling the onboard capacity.

2. Comparisons with LHA, LHD and LPH Class Vessels

The AFFF capability on these decks is significantly behind that found on attack carriers, and a program is underway to upgrade these systems by FY88. When these improvements are completed, the capabilities will be comparable.

The LHA flightdecks have flushdeck sprinklers similar to those on attack carriers. These are arranged in six zones and supplied by six HI-CAP stations. Unlike the carriers, the zones have a common manifold, and any HI-CAP station can supply any zone under certain conditions. The storage capacity of the HI-CAP is presently 300 gallons and will be increased to 1,000 gallons.

The LHD flightdecks, when they are introduced to the fleet, will have systems similar to the LHA class decks. The capacity of the HI-CAP stations will be 2,000 gallons, and there may be more stations and zones.

The LPH flightdecks do not have flushdeck sprinkler nozzles; instead they are provided with deck-edge nozzles which do not provide even coverage. Generally, the coverage is estimated at only 80 percent. A large bare spot around the island will be provided with flushdeck nozzles in the upcoming improvement program. The deck-edge nozzles are installed close to the deck, pointing inboard where the streams are easily masked by objects on the deck such as aircraft and support equipment. Two additional hose stations are being installed near the bow to improve fire protection up forward.

The deck-edge nozzles are arranged in zones served by five HI-CAP stations through an H-shaped distribution system providing mutual support. All HI-CAP stations will be provided with a 600-gallon storage tank; presently some have only a 300-gallon tank. A central AFFF storage and transfer system is being installed with two 750-gallon storage tanks.

The control system for the AFFF equipment on LHA, LHD and LPH decks is similar in organization to the attack carriers. Remote activation is provided to the Primary Flight Control and to the Bridge. The electrical controls do not always provide the

full flexibility of the zone arrangement. This limitation is subject to improvement.

3. Auxiliary Agents and Extinguishers

The auxiliary agents used with shipboard aircraft are CO_2 and P-K-P. CO_2 is available in portable extinguishers found along the flightdeck catwalk, the hangardeck bulkheads and on the mobile firefighting equipment. It is used for engine and tailpipe fires, battery fires and cockpit fires. P-K-P is available in portable extinguishers and in larger extinguishing systems built into the mobile firefighting equipment. It is used on debris piles and running fuel fires, and as a last resort, where CO_2 has been tried without success. Halon 1301 is used in fire-extinguishing systems on some aircraft, and Halon 1211 is being considered for retrofit on some mobile equipment. These agents supplement the capabilities of AFFF.

4. Ship Maneuvers

The firefighting plan calls for ship maneuvers to control the wind-over-deck. During flight operations the ship is normally heading into the wind with a wind-over-deck at 15-30 knots. In an emergency the captain will change course to bring the wind direction around to protect nearby aircraft and allow upwind approach to firefighting activities. He will also adjust the ship's speed to bring the wind-over-deck to 5 knots. Depending on the extent of maneuvering required, this may take from 3 to 15 minutes to complete.

D. FLIGHT OPERATIONS AND HAZARDS

Fire hazards present during flight operations are briefly described. General plans for crash and rescue response are presented.

1. Operations On Attack Carriers

Launching evolutions involve certain hazards in the pre-launch pack and in the catapult-launch procedure. In the prelaunch pack the planes are closely spotted, only allowing space for a fire lane. During prelaunch, ordnance and fueling evolutions are performed, LOX is loaded, and engines are started in sequence.

From this position, plane directors move individual aircraft to a ready position behind the jet-blast deflector and then out to the catapult. Before hookup to the catapult, the forward-firing weapons are armed and final checkouts completed.

Fire protection throughout this sequence is provided by the ship's systems and the two fire trucks. These vehicles are positioned between the catapults at the bow and at the waist. From these locations, their only hindrance to movement would be aircraft in the ready positions. Small, maneuverable vehicles are used.

For recovery operations, all aircraft are spotted clear of the foul line so that the angle deck can serve as the landing

area. The approaches of all aircraft are monitored carefully. The impact of a steep approach can push the landing gear up through the wing structure, while a shallow approach can cause the plane to strike the ramp. The result in either case is a crash in the landing area. Special problems can arise if an aircraft spins out of the landing area after touchdown. Spinning left will send it into the catwalk; spinning right will send it into the recovery pack and can result in a multiplane incident. A likely place for this kind of incident to occur is the area near catapult number two, but this is not the only possible place.

After coming to a stop and unhooking from the arresting cable, the aircraft is directed toward the "safing hole", where forward firing weapons are disarmed, and then toward its spot in the recovery pack. The arrangement of aircraft in the recovery pack is carefully planned to provide fire lanes, but the limited space available presents problems for large recoveries. The last part of large recoveries blocks the fire lane on the bow, keeping a fire truck from providing protection for these aircraft.

In the recovery pack, fuel and ordnance evolutions are conducted, LOX is loaded, and engine starts and stops are made under close supervision. The close spacing of aircraft and congested fire lanes make these operations especially hazardous.

During recovery operations, one truck is positioned on the bow upwind of all fueling operations. The second truck covers the landing area from a position near "the point." When the fire lane on the bow is being used to spot aircraft, the forwardmost truck is sometimes progressively moved aft to avoid being blocked, and only the forwardmost hose stations on the bow are able to provide upwind coverage.

2. Operations on LPH, LHA and LHD Flightdecks

These decks are organized primarily for helicopter operations. Takeoffs and landings are made from designated spots on the port side of the foul line. Approach and departure angles are usually diagonal to the deck centerline and the relative speed is very low. Operations are sequenced to avoid simultaneous use of nearby landing spots.

Procedures are slightly different for the AV-8 and OV-10 aircraft. AV-8 landings are similar to helicopters, but they normally take off in a more conventional manner to save fuel. OV-10 aircraft are conventional in both takeoff and landing. The speeds of both AV-8s and OV-10s are low and the distance needed for takeoff and landing is short.

The aircraft are spotted on the starboard side of the foul line. Fueling and some ordnance evolutions are performed here, but engines are normally not run. On LPH class decks, the

fuel hose stations are on the port side, presenting the problem of exposed fuel lines running across the flightdeck.

Crashes on these decks are less frequent and of lesser magnitude than on attack carriers. Landing speeds are lower, and except for some AV-8 evolutions, the overall pace is slower. However, helicopters tend to roll over in a crash and a pilot may overshoot his approach, crash, roll over the foul line, and involve other aircraft in the incident. The present configuration of the shipboard firefighting systems on these decks can cause an incident to quickly get out of hand.

Ordnance is handled in much the same way as on the carrier decks and air-launched ordnance presents an identical hazard. Other types of ordnance are normally carried as cargo on helicopters. Since this ordnance has no identified cook-off characteristics and is not encased in protective containers, handling creates a distinct problem from a fire protection perspective. Furthermore, loading plans are not normally formulated to minimize the risk. This potentially serious problem is peculiar to this class of flightdecks.

3. Hangardeck Hazards

Except for the landing area crashes, the hazards on hangardecks are much the same as on flightdecks. Fueling and ordnance evolutions are performed, although the procedures are more restricted. LOX is not handled and no high-powered turn-ups

are permitted. In bad weather, when aircraft from the flightdeck may be stored here, an aircraft may break loose from its lashings and cause considerable damage. The crowded conditions prevalent on the hangardeck preclude adequate fire lanes for fire trucks. However, serious incidents on a hangardeck are rare.

4. Crash Crew Response

Basic minimum response to flightdeck fires consists of one truck, two hose teams and a scene leader. Other personnel form a line and organize themselves into teams to perform tasks assigned by the scene leader. In practice, most ships respond with more than two hose teams, and the second truck advances to a position from which it can quickly engage the fire, if needed. Most LPH and LHA flightdecks do not have fire trucks.

The hose teams are quickly formed from flightdeck personnel who happen to be close to the fire and a hose station. These personnel are trained in basic firefighting techniques. A few individuals may have received additional training, but only rarely would this training have included any aviation firefighting.

Fire trucks are manned by the crash crew. The crew is equipped with hotsuits and may have received a 1- or 2-day course in aviation firefighting. Since schools do not have the type of fire truck used on flightdecks, crash crews experience only on-the-job training (OJT). OJT averages from two to three responses

per week, while at sea, with or without fires. Actual crashes happen very infrequently; when one occurs, it is a first experience for most people on the flightdeck.

5. Rescue Operations

Present Navy doctrine on this subject is "fire containment - then rescue," recognizing the serious hazards for personnel on the flightdeck, as well as for the pilot and air crew.

Crash crews are organized so that two hotsuitmen are designated for rescue and will report to the scene leader in any emergency. In some instances these individuals and their tool rolls are stationed on the fire truck to ride to the fire where they serve as handlinesmen, or rescuemen, as required. In other cases hotsuitmen respond from a station near "the island."

Additional rescue equipment is available on a 6-K forklift. This forklift has a rescue pallet to raise the rescuemen to the elevation of the cockpit. A corpsman is also available during Flight Quarters to assist in the rescue.

Crash experiences indicate that the pilot is often able to get clear of the aircraft on his own. In the event of a survivable crash from which the pilot is unable to make his own escape, some difficulty could result from using the rescuemen as handline operators. If a rescueman is needed first as a handlinesman and then as a rescueman, the individual taking over the handlines may have had little or no training in the use of the

handlines. In practice, the scene leader controls this problem by waiting until the fire is contained before ordering the rescue, leaving only "mop-up" firefighting evolutions to be conducted. Complications might arise, however, if more than one plane is involved and the scene leader must choose between fighting the fire on one aircraft and rescuing the pilot on another.

Another approach is under discussion which would divorce all rescue operations from the fire truck. The men dedicated for rescue would approach the crash scene by any available means and stand by for instructions from the scene leader. In this way, these men would be available for both firefighting or rescue, as the situation may dictate. The fire truck, on the other hand, can be designed specifically for the mission of fighting fires, using as few firefighters as practicable.

SECTION IV

MOBILE VEHICLE MISSION REQUIREMENTS

A definition of the role a fire truck should play is proposed for use in aviation firefighting on aircraft carriers. Specific tasks are explained. The future effects that improved safety of aircraft and ordnance will have on mission requirements in the future are also discussed.

A. STATEMENT OF MISSION

The primary mission of the fire truck is rapid initial response for suppression of all flightdeck fires and for ordnance protection whenever appropriate. Included are fires involving aircraft, ship systems and support equipment, as well as crash fires and ordnance incidents.

Several secondary missions can be defined. The truck may be used to respond to fires on the hangardeck. The truck should be capable of supplementing other shipboard firefighting system during and after the period of initial response. It should also be capable of providing fire protection for personnel involved in other firefighting, rescue and ordnance protection operations during later phases of the incident. It should be designed to transport only the equipment and key personnel required for the primary firefighting mission.

B. RAPID INITIAL RESPONSE

Rapid initial response includes all firefighting efforts made within the first minute after ignition. Fuel fires spread and intensify rapidly at a crash scene and must be dealt with within the first minute. Catwalk hose teams and shipboard sprinkler systems also have a rapid initial response capability, but the fire truck should be designed to respond within the first minute.

In limiting the primary mission of the truck to rapid initial response, it is recognized that improvements are being made to the shipboard firefighting systems on the LHA and LPH class flightdecks. In their present configuration, the systems on these decks are much less capable of coping with a major incident, and the role of a suitable fire truck should be proportionately greater. By FY88 the LHA and LPH system capability should be comparable to that on the CV class flightdecks; consequently, the need for mobile equipment will be equivalent.

C. TYPES OF FIRES

Common flightdeck fires involving aircraft include engine and tailpipe fires, fuel spills, overheated batteries and other electrical fires. Flightdeck equipment with demonstrated fire hazard potential includes the catapult troughs and fuel manifolds in the catwalk areas. Engine compartments on support equipment are also subject to fires. Fuel spills and overheated batteries can often be detected before a fire breaks out, but appropriate

response is still necessary. The fire truck should be able to respond promptly to all these incidents.

Potentially more serious are the incidents which result in damaged aircraft such as crash landings and accidental discharge of weapons. The distinction is due to the large volume of fuel and the number of aircraft which can become involved. Complications from debris and from fuel flowing from ruptured tanks make firefighting more difficult. These incidents require a large capability for adequate response.

D. ORDNANCE COOLING

The number of air-launched weapons in the inventory with short cook-off times requires that some initial response be directed toward protecting the ordnance whenever it might be subjected to heat. This includes weapons external to the aircraft and in the bomb bay inside the fuselage. The threat of violent reactions from ordnance may be significantly reduced by the completion of the present ordnance safety program (roughly 10 years); however, the difficulty in dealing with the burning reactions of some materials used in these weapons will remain. Therefore, some degree of initial protection should be given to these weapons even after the program's objectives have been achieved. The fire truck must have an ordnance cooling capability for the next several years and perhaps indefinitely.

E. APPLICABILITY TO HANGARDECKS

The fire hazards on the hangardeck are mostly associated with common aircraft fires and require a lesser degree of protection. While rapid initial response is just as important, the capabilities required for response to a crash fire are more than adequate for dealing with incidents in the hangardeck environment. Because congestion is a concern, protection for the hangardeck should rely more on smaller fire trucks and fixed systems.

F. SUPPLEMENTAL FIREFIGHTING CAPABILITY

Following initial response, the fire truck will assume a secondary role in the sustained firefighting effort. After the shipboard systems are deployed, the scene leader may direct the fire truck to one of several assignments to supplement these systems. Special use may be made of any residual agents or special applicators carried by the truck. If sufficient agent is left or nursing hoses are available, the truck may continue in a general firefighting/ordnance-cooling mode or it may be positioned for backup protection for hosemen and rescue personnel. The truck should, therefore, feature all these capabilities.

G. FIRE SIZE CRITERIA

Criteria must be selected for determining the magnitude of response needed to accomplish the mission of the fire truck. Response to crash fires and similar events is the most demanding

task foreseen on flightdecks, and it is recommended that the truck be designed around a single-aircraft incident for two reasons: high probability and rapid identification.

Most flightdeck crashes involve a single aircraft and occur in the landing area. Aircraft handling procedures and approach control techniques have proven effective in protecting the aircraft from such an event. When a second aircraft is involved, or is likely to become involved, the situation can be quickly identified by most observers on the flightdeck. Crash crews can respond to multiplane incidents in a different manner without hesitation. The fire truck is not intended for use against a single aircraft incident without any support from the shipboard firefighting systems, but its capabilities should be defined in those terms insofar as those capabilities can be identified.

SECTION V

FIRE-SUPPRESSION REQUIREMENTS

The application of Critical Fire Area Analysis for determining fire-suppression requirements on Navy flightdecks is considered. Modifications to the basic approach are suggested and judgments are made concerning application rates, agent types, and application techniques.

A. CRITICAL FIRE AREA ANALYSIS

This analytical technique has been in development for some years for planning fire protection for airports and airfields. It provides a semiempirical technique for using the size of the aircraft to determine the area around the plane which, when engulfed in a fuel fire, threatens the contents of the fuselage. Experimental measurements have been made using the skin burn-through criteria, and these results have been compared with crash statistics from around the world. A relationship for this area has been found which can be expressed as follows:

$$\text{area} = 2/3\ [\text{fuselage length} \times (\text{width} + 40\ \text{feet})]$$

Larger aircraft require disproportionately more protection, and for aircraft over 65 feet in length, 100 feet are added to the fuselage width instead of the 40 feet used in the above expression. The fractional coefficient arises from the comparison of field tests with observations of actual crash experience. Wind, terrain and the crash configuration are known

to affect the boundaries of the critical fire area, but experience has shown that limits can be placed on its size with good reliability and with conservative results.

With the critical fire area defined, what remains is a deciding on an application rate appropriate for the conditions at the crash site (assuming the entire critical fire area is involved in flames). For AFFF against JP-4 fuels, application densities from 0.05 to 0.15 gpm/ft^2 are suggested, due to the better response of JP-4 fuel to AFFF at ordinary temperatures. This suggested range of application densities provides a wide latitude of discretion for airport fire protection planners who must take into account the many special circumstances that may confront them.

B. APPLICATION TO FLIGHTDECKS

Some unique aspects of naval aviation must be considered in applying this experience to rapid intervention of crash fires on flightdecks. On the minus side is the presence of weapons outside the fuselage and the unusually high winds, while on the plus side are the capabilities of the fixed firefighting systems. The absence of passengers is not considered a plus because the space not used by pilot and aircrew is normally loaded with weapons, fuel tanks, and LOX converters.

Externally carried weapons and high winds increase the area which must be brought under control. The wind will carry heat to the aircraft a greater distance from any fire in the upwind

direction, and may not produce an offsetting effect on the downwind side due to disturbed wind patterns at the crash site. The weapons under the wing are not shielded by the skin of the aircraft and special allowance for this might also be made in the size of the critical fire area.

Both the flushdeck system and the catwalk hoses have an initial response capability, but they affect the analysis in different ways. The flushdeck sprinklers in the immediate vicinity of the crash may be blocked by debris and lose effectiveness inside the critical fire area; outside of vicinity, however, it will be much more effective. This reduces the area to be protected by the mobile equipment, or in the context of the analysis, the critical fire area.

The hose teams reaching the scene in this early phase will increase the application rate available within the critical fire area. In high wind conditions, this can be important. They offer the additional advantage of providing additional streams for reaching zones otherwise obscured from the fire truck, improving overall application efficiency.

When appropriate allowance is made for these conditions on a flightdeck, the analysis can be applied to the mission of the fire truck where immediate response must be directed at the crash site to protect personnel and weapons; i.e. the critical fire area. It brings together test results and crash experience, and

provides for discretionary judgments to suit special circumstances. In its present form the analysis is limited to single-aircraft events; however, within this limitation, it is a worst-case analysis that assumes the entire critical fire area to be involved in the fire.

C. AFFF APPLICATION RATE

Tables 5 and 6 show the application of the Critical Fire Area Analysis to carrier flightdecks and to LPH and LHA flightdecks respectively. Columns 1 and 2 list the aircraft and fuselage length for the planes typical of each type of deck. Column 3 shows the critical fire area as determined in the manner appropriate to land-based crashes with only one exception.

TABLE 5. PROTECTION FOR COMMON CV AIRCRAFT

AIRCRAFT TYPE	AIRCRAFT LENGTH Ft	CRITICAL FIRE AREA a Sq Ft	MODIFIED FIRE AREA b Sq Ft	APPLICATION DENSITY c gpm/Sq Ft
A-6E	55	1833	2750	.09
A-7E	47	1567	2350	.11
F-4B	58	1933	2900	.09
F-14A	63	2100	3150	.08
F/A-18	56	1867	2800	.09
EA-6B	59	1967	2950	.08
E-2C	58	1933	2900	.09
KA-3B	76	2533	3800	.07
KA-6D	55	1833	2750	.09
C-2A	56	1867	2800	.09
S-3A	53	1767	2650	.09
SH-3H	47	1567	2350	.11
SH-60B	50	1667	2500	.10

a area = 2/3 (length x 50 ft)
b 1.5 x area for weapons and wind effect
c @ 250 gpm

TABLE 6. PROTECTION FOR COMMON LHA AND LPN AIRCRAFT

AIRCRAFT TYPE	AIRCRAFT LENGTH Ft	CRITICAL FIRE AREA a Sq Ft	MODIFIED FIRE AREA b Sq Ft	APPLICATION DENSITY c gpm/Sq Ft
AV-8B	46	1533	2300	.11
OV-10A	40	1333	2000	.13
AH-1T	45	1500	2250	.11
UH-1N	42	1400	2100	.12
SH-3H	47	1567	2350	.11
CH-46D	46	1533	2300	.11
CH-53E	56	1867	2800	.09

a area = 2/3 (length x 50 ft)
b 1.5 x area for weapons and wind effect
c @ 250 gpm

For the KA-3B in Table 5, the width parameter used in the critical fire area calculation is the same as that used on the aircraft under 65 feet in length. This is justified by the effectiveness of the flushdeck sprinklers outside the area of aircraft debris. However, no credit is given for any effect close to the aircraft.

The critical fire area is modified to provide for flightdeck conditions in Column 4. The effects of wind and exposed weapons are offset by the effect of the flushdeck sprinklers, but no generally accepted criteria are available for determining the degree to which these effects compensate for each other. To be conservative, a safety margin of 50 percent is applied as shown.

Finally, the application density for a single 250 gpm nozzle stream applied to the modified fire area is shown in Column 5. No credit is taken for assistance from the shipboard systems, and

no allowance for wind losses has been made. The situation on the two types of flightdecks is comparable, and the application densities are all well above the accepted minimums. This rate is recommended as the rate appropriate for the Navy's rapid-response firefighting vehicle.

D. AUXILIARY AGENTS

One or more auxiliary agents are needed to achieve a three-dimensional capability. Common aircraft fires and crash fires include internal fires. Crashes often result in running fuel and debris piles for which AFFF alone is not effective. Both Halon 1211 and P-K-P have advantages, but no clear basis exists for making a selection. Halon is a clean agent and a good choice for engine and tailpipe fires, and for internal fires involving personnel and salvageable equipment. For external use against running fuel fires and debris piles exposed to winds over 5 knots, P-K-P may have some advantages. The agents cannot be employed together because their capabilities cancel each other, hence the combination of Halon and P-K-P is ineffective.

Table 7 shows the results of extensive comparison testing by the U.S. Air Force for three-dimensional agents in aircraft firefighting. The ratings indicate where one agent is superior to the other and where the two are equivalent but Halon is favored because it is a clean agent.

TABLE 7. COMPARISON OF AUXILIARY AGENTS IN AIRCRAFT FIRE*

FIRE TYPE	HALON 1211	DRY CHEMICAL
Tires	Preferred	Limited
Fuel Spills	Limited	Preferred
Engines	Preferred	Limited
Flowing Fuel	Limited	Preferred
Helo Stacks	Preferred	Good
Interiors	Preferred	Limited
Electrical	Preferred	Good
Support Equipment	Preferred	Good

* Source: U.S. Air Force

The Navy has conducted tests on flowing fuel fires using the combination of Halon 1211 and AFFF with positive results. Used in this way, Halon is believed to be at least as effective as P-K-P and may have a slight advantage. Therefore, it is recommended that Halon 1211 be incorporated into the truck design to provide it with a three-dimensional capability.

E. ENDURANCE

The primary mission of the truck requires it to perform appropriate tasks during the first 60 seconds of a fire or crash. To be able to complete those tasks and revert to whatever support task the scene leader may direct, the truck must be capable to operate for at least 90 seconds using its own resources. For ordnance cooling, an endurance of 15 minutes may be required; therefore, a nursing connection is recommended.

F. APPLICATION TECHNIQUE

Aviation firefighting is as much a matter of technique as it is of gross numbers, and is especially true on flightdecks. The nozzles and applicators must be appropriate for use in high, gusty winds. This generally calls for a sweeping action applied to solid streams; furthermore, the streams must stay close to the deck. Close-range techniques are also needed. In its primary role, the truck must be equipped to pump on the run; in a secondary role, such as ordnance cooling or personnel protection, the truck must also function in a park and locked mode. The truck must also provide for the use of penetrating and other special-purpose applicators.

G. MULTIPLANE INCIDENTS

The analysis attempts to predict the worst-case result of a single-aircraft incident and indicates critical fire areas between 2,000 and 4,000 square feet. Recent incidents aboard aircraft carriers have resulted in multiplane incidents when planes were so closely spotted that the critical fire areas overlapped almost completely.

Multiplane incidents can present a complicated crash geometry and are likely to occur where wind, nearby aircraft, and deck space restrict access to the crash site. Recent examples of this kind show that good coverage can only be provided when several

streams can be used simultaneously. The standard, minimum response of one truck and two hoses can be easily outmatched, especially when weapons are involved, and when response is delayed. An incident of this magnitude, or one likely to become this threatening, may require a wider response, but it does not necessarily require a larger truck.

SECTION VI

VEHICULAR REQUIREMENTS

Mobility requirements which derive from the mission or from conditions on a flightdeck are described.

A. SPEED AND ACCELERATION

For rapid responses over short distances the starting and stopping distances must be short. The truck should be able to travel 500 feet start to stop in 20 seconds or less. A top speed of 20 to 25 miles per hour is sufficient. This assumes a flat, still deck with nonskid coating.

B. STARTING TORQUE

The drive train should develop sufficient starting torque to climb over a 2-1/2 inch fire hose and to climb a 20 percent slope at low speed with a full load. This will enable the truck to climb a ramp for servicing at sea.

C. MANEUVERABILITY

The congested space on a flightdeck requires this truck to have a low, narrow profile and a short wall-to-wall turning diameter. To complement this capability, the center of gravity must be kept as low as possible for all loading conditions. It is not necessary to make sharp corners at full speed, but every advantage must be given to rapid turning in tight spaces.

SECTION VII

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. Aircraft Materials and Hazards

Developments in crash safety design can be expected to reduce the severity of postcrash fires involving naval aircraft in the next 10 years. The largest single problem continues to be fuel. Safety features planned for implementation between now and then should result in fewer fuel tank explosions. The risk of oxygen-enriched fires will be virtually eliminated with the implementation of the OBOGS program. However, fires from ruptured fuel tanks will remain the most serious threat.

Composite materials have a rapid burn-through time (less than 1 minute) similar to the aluminum being replaced. Magnesium will be present at least as long as the present generation of aircraft remains in service. Use of titanium will continue at about the same level for the foreseeable future.

Lithium is the only new hazard noted. Assessment of its practical hazards depends on the effectiveness of its thermal protection, the means of fire protection provided by the aircraft, and training of crash crews in dealing with the hazard.

2. Air-Launched Ordnance

The presence of air-launched ordnance continues to constitute the chief complication to fires involving naval

aircraft. The predictability of the cook-off process of this type of ordnance remains low. Coupled with the difficulty of predicting the ordnance cooling process, test results are difficult to interpret. Measured cook-off time derived from the test of a particular weapon does not fully describe the problems likely to be encountered in an actual firefighting situation.

3. Existing Shipboard Firefighting Equipment

The flightdeck nozzles have proven themselves effective in suppressing pool fires and in containing running fuel fires. When properly maintained, the nozzles can provide even coverage to a clear deck within a few seconds. Common problems are due to inadequate maintenance and obscured streams. Coverage from the deck-edge nozzles is more unpredictable because aircraft and support equipment can easily block these streams and leave portions of the deck without adequate protection. Wind effects can also reduce coverage. Catwalk areas and elevator decks are not evenly protected by these nozzles.

Hose streams are also effective for fire suppression. Supplementing the uneven coverage of the fixed nozzles, hose streams can be directed more precisely against engine and tailpipe fires, debris piles, and running fuel fires. With quick response and good technique, hose streams have wide application in firefighting, especially when used with appropriate auxiliary agents.

The capabilities on the hangardeck are similar to that on the flightdeck. General coverage is provided by overhead sprinklers which are subject to masking by the aircraft structures. Hose streams provide the principal weapon against aircraft fires by providing for direct, close-in application. The hangardeck has better wind protection, allowing auxiliary agents to be used with greater effect.

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